

**Table 4.4.2 Estimated Time to Rehabilitate the
Kennedy Creek Check and Wasteway Structures**

Task	Duration
1) Feasibility Study	2 months
2) Final Design	4 months
3) Construction Phase	12-14 months
TOTAL TIME	18-20 months

4.5 ST. MARY AND HALLS COULEE SIPHONS

4.5.1 Structure Overview

St. Mary River Siphon

The St. Mary River Siphon is one of the most significant features of the 29 miles of the St. Mary River Diversion Facilities. The inverted siphon consists of two riveted steel pipes ranging in diameter from 84 to 90 inches. The 90-inch pipe transitions to an 84-inch diameter as it crosses the St. Mary River Bridge and then back to 90 inches (See Figures 4.5.1 and 4.5.2). The overall siphon length varies from reported lengths of 3,205 to 3,230 feet long. The original wall thickness of the pipes varies from 1/4-inch to 3/8-inch, depending on its location. The discharge capacity of each pipe is 425 cfs for a combined capacity of 850 cfs. Water velocities range from 9.63 to 11.05 fps for the two different diameters. The maximum static head is 165 feet (71.5 psi) which is the elevation difference between the inlet water level and the center of the pipes crossing the bridge. The siphon inlet and outlet are concrete transition structures (Figures 4.5.3 and 4.5.4).



Figure 4.5.1 St. Mary River Siphon, looking upstream (northwest) across St. Mary River (10/13/04).



Figure 4.5.2 View of the St. Mary River Bridge carrying the siphon (06/04/04).



Figure 4.5.3 St. Mary River Siphon Inlet Structure (10/13/04).



Figure 4.5.4 St. Mary River Siphon Outlet Structure (10/13/04).

For orientation purposes, the steel pipe is referred to as the “left pipe” (north pipe) and the “right pipe” (south pipe) when viewing downstream.

The left pipe was constructed from 1912 to 1915, and the right pipe was constructed from 1925 to 1926. Most of the left pipe was placed underground with 3 to 5 feet of soil cover. The water diversion started in June of 1916 with just the left pipe. After nine years of operation, the left pipe underwent a major repair due to damage from corrosion, compression buckling, and development of major leaks. Because of this, it was decided that the right pipe should be constructed above ground on concrete saddles on 20-foot centers to support the pipe. This also facilitated maintenance of the outside protective coating. It was also decided to use more expansion/contraction joints and increase the internal joint movement distance from 10 inches to 24 inches. A typical expansion/contraction joint with a cathodic continuity cable is shown in Figure 4.5.5.

During the 1926 operation season, the newly constructed right pipe failed at the outlet transition. The pipe moved downslope such that approximately 100 lineal feet collapsed or was damaged. The repair was made by constructing an anchor just upstream of the outlet transition to stabilize the pipe and prevent it from moving downslope.



Figure 4.5.5 St. Mary River Siphon - Typical Expansion/Contraction Joint, Including Cathodic Protection Continuity Cable (10/26/04).

In the Spring of 1937, the left pipe underwent a major renovation which took place over two years. The earth material was removed from the left pipe and concrete supports were constructed under the portions of the pipe that laid on the ground in the trench. Both pipes were recoated at that time.

In 1954, a section of the left pipe was replaced and steel plates were installed where corrosion had damaged the steel. Figures 4.5.6 and 4.5.7 show typical siphon repairs due to deflection and corrosion. Also, there appeared to be seepage from the canal which moved along the siphon support foundation at both pipes. The left pipe was further unearthed and a perforated drain pipe installed, surrounded with well-graded gravel. One drain was installed on the north side of the left pipe, and one on the south side of the right pipe. A cathodic protection system was also installed on both pipes. This system remained in effect until 1997 when the pole support for the rectifier tipped over damaging the rectifier beyond repair.



Figure 4.5.6 Typical siphon repair due to deflection and/or corrosion (10/13/04).



Figure 4.5.7 Typical siphon repair due to deflection and/or corrosion (10/13/04).

In 1986, the insides of both pipes were sandblasted and repainted with coal tar epoxy. Several sections of the left pipe were replaced because of extensive corrosion.

The left siphon between Station 512+30 (location of the most downstream pipe anchor) and Station 518+21 (downstream end of steel pipe) has been a major problem area. Part of this section has moved up to 4.5 feet downslope since the pipe was constructed. The movement caused major compression buckling near Station 513+00.

An inspection in the Fall of 1996 revealed complete closure of all the expansion joints in the left siphon, which resulted in compression buckling. This also caused the pipe supports to rotate downslope which created a point-load bearing condition. This resulted in up to 6-inch indentations in the pipe at the points of the concentrated load (Figure 4.5.8).



Figure 4.5.8 Photo shows ground movements right to left causing rotation of concrete support and point-loading of siphon which can lead to buckling (10/13/04).

The right siphon exhibits similar movement, but because this pipe was constructed with a different type of expansion joint, this allowed the pipe to accommodate more movement. In any event, several of the right siphon expansion joints also became entirely closed.

In June 1996, there was a significant amount of surface water which appeared to be coming from leaks in both siphons along the north slope. This resulted in erosion and loss of support for the left pipe at a vertical change in slope.

Repairs were carried out in February 1997. The work done is listed as follows:

- Buckled section in left pipe was replaced.
- The expansion joint near the buckled section was re-done.
- A seven-inch long extension was welded to the downstream end of the left pipe.
- The male ends in two expansion joints in the right siphon were cut and repaired to make them again operable.

Halls Coulee Siphon

Similar to that of the St. Mary River Siphon, Halls Coulee Siphon (Figure 4.5.9) was constructed in two phases: 1912 to 1915 and 1925 to 1926. These siphons, approximately 1405 feet each, are also rivet steel conduits, have a 78-inch diameter and a combined design capacity of 850 cfs. The original wall thickness of the pipes was 1/4-inch. The first pipe was buried except along the bottom of the coulee. Due to problems associated with the St. Mary River Siphon, the second pipe at Halls Coulee was constructed above ground and supported on similar concrete saddles (Figure 4.5.10). The siphons at Halls Coulee are relatively stable compared to the St. Mary River Siphon but have experienced some minor problems with sliding, leakage and closure of expansion/contraction joints.



Figure 4.5.9 Looking downstream (southeast) along Halls Coulee Siphon (10/13/04).



Figure 4.5.10 Photo shows concrete failure of a Halls Coulee Siphon support saddle (10/13/04).

4.5.2 Existing Conditions & Deficiencies

St. Mary River Siphon

The existing works have problems described as follows:

- Inlet and outlet structures have large areas of delaminated concrete and spalls.
- There are substantial voids under the concrete apron of the outlet structure.
- The exposed concrete pipe supports are deteriorating.
- Concrete on the bridge abutments and center pier also needs to be replaced.
- The left conduit continues to slide down the slope.
- Concrete supports under the conduit are rotating because of ground movements relative to the pipe. As the supports tip they buckle the bottom of the pipe.
- Portions of the conduit continually need to be removed at the expansion/contraction joints to keep them functional. Additional lengths of conduit need to be added to replace displaced sections.
- Most of the expansion/contraction joints are leaking and have saturated the hillsides (see Figure 4.5.11).



Figure 4.5.11 Leaking expansion/contraction joint on St. Mary River Siphon. Note erosion of supporting soil (10/13/04).

This siphon was inspected on two occasions: on October 13, 2004 and on October 26, 2004. On October 26, 2004, detailed inspections were done of the insides of both siphon pipes.

The people who worked on the October 26, 2004 inspection are listed as follows:

- Dave Firewick, Civil Engineering Technologist, BOR
- Jerry C. Moore, Civil Engineer, Volunteer (Retired from BOR)
- Dave Scanson, Civil Engineer, BOR
- Bill McStraw, Engineer, BOR
- James Keith, Engineer, BOR
- Irv Martens, Civil Engineer, UMA Engineering Ltd.

The work consisted of the following:

- Marking each siphon conduit at 50 feet intervals, and more often wherever problems were identified.
- Taking horizontal and vertical measurements of the siphon, at least every 50 feet, and noting deficiencies. Photos were taken of deficiencies.
- Taking wall thicknesses of the conduits, at or near invert locations, at least every 50 lineal feet.

The results of this inspection confirmed information found in previous reports, namely:

- Concrete supports under the conduit are rotating. As the supports rotate, they crimp the bottom of the pipes.
- Portions of the conduits have slid downslope causing expansion/contraction joints to close, and compression buckling of the siphon barrels.
- Expansion/contraction joints are leaking.
- Some sections of the siphon barrel have been replaced with welded steel pipe.
- Generally the left siphon was found to be in worse condition than the right siphon.

Several items were noted which were not found in previous reports. These are:

- Large portions of the siphons are egg-shaped. The most extreme egg-shaped siphons and the corresponding horizontal and vertical measurements were noted as follows:

**Table 4.5.1 Internal Siphon Dimensions of
St. Mary River Crossing Measured Fall 2004**

Left Pipe - St. Mary River Crossing		
Station (ft)	Horizontal Width (ft)	Vertical Height (ft)
486+50	8'-0"	7'-3"
487+00	8'-4"	6'-10"
487+50	8'-0"	7'-1"
491+00	8'-2"	7'-1"
491+50	8'-2"	6'-11"
493+00	8'-0"	7'-3"
515+38	8'-0"	7'-1"
515+50	8'-1"	7'-1"
516+50	8'-0"	7'-1"
Right Pipe - St. Mary River Crossing		
Station (ft)	Horizontal Width (ft)	Vertical Height (ft)
492+69	7'-1"	7'-4"
492+89	8'-0"	7'-2"
493+00	7'-10"	7'-5"
517+70	8'-6"	6'-11"
518+00	8'-5"	6'-11"
518+23	8'-1"	7'-0"

Note: Original diameter was 7'-6".

- Bolt heads are sticking up approximately 4 inches above siphon invert near the downstream end of the left siphon.
- The thinnest wall thickness was measured to be 0.23 inches.
- Circumferential cracks were noted in the steel of the right siphon, at Station 518+00. From the discussion at the site, it was understood that these cracks will be repaired prior to the next operating season.

Another observation that was made during the October 13, 2004 inspection is listed as follows:

- Rebar is exposed at the floor of the concrete inlet transition of the right siphon.
- Photos were taken of typical deteriorated areas of the siphons and are shown on Figures 4.5.12 through 4.5.15.

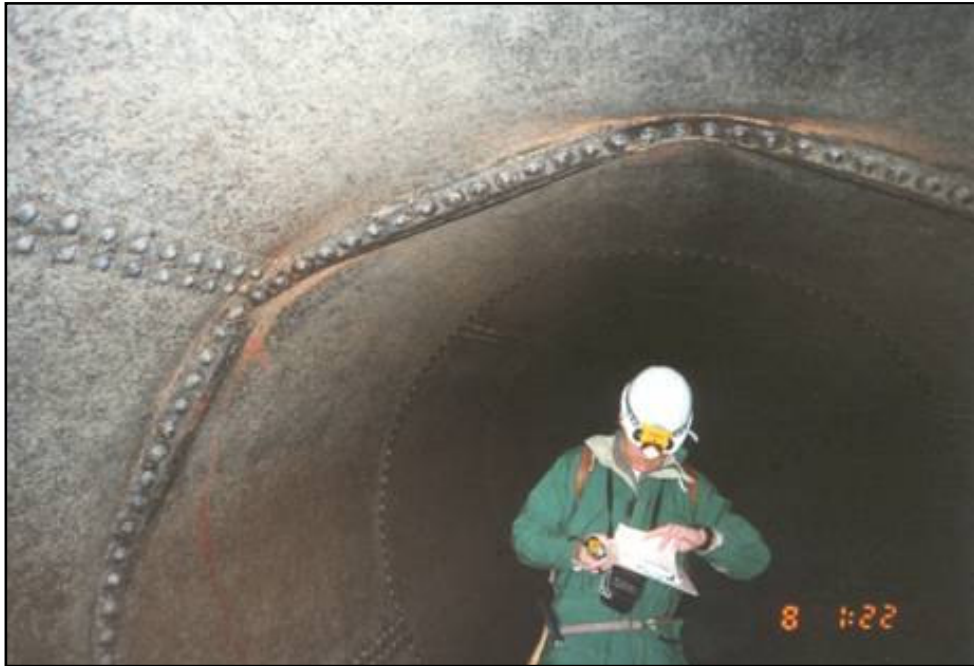


Figure 4.5.12 Typical Buckling at the Top of St. Mary River Siphon (10/26/04).



Figure 4.5.13 Typical Buckling at the Bottom of St. Mary River Siphon (10/26/04).



Figure 4.5.14 Cracks in the Steel Near the Downstream End of the Right St. Mary River Siphon (10/26/04).



Figure 4.5.15 Exposed part of left siphon where expansion/contraction joint has closed. This joint was being replaced in the Fall 2004 (10/26/04).

Halls Coulee Siphon

The existing works have problems described as follows:

- The inlet and outlet structures have areas of delaminated concrete and spalls.
- The exposed concrete pipe supports are deteriorating.
- The expansion/contraction joints are leaking.
- The steel pipe walls are becoming thin and are difficult to repair.

This siphon was inspected on two occasions; on October 13, 2004, and on October 27, 2004. The inspection of October 27, 2004 was done by the same people who inspected the St. Mary River Siphon on October 26, 2004. A similar procedure was followed for this siphon.

The results of this inspection confirmed information found in previous reports, namely:

- There are indications of conduits sliding downslope causing expansion/contraction joints to close to some extent, and resulting in compression buckling of the pipes. However, this phenomenon is considerably less pronounced at Halls Coulee compared to the St. Mary River siphon.
- The steel pipe walls are becoming thin. Wall thicknesses as low as 0.19-inch were recorded, which is significantly less than the minimum wall thickness of 0.23-inch recorded at St. Mary River Siphon.
- Expansion/contraction joints are leaking.

Several items were noted which were not found in previous reports. These are:

- Large portions of the siphon barrels are egg-shaped. The most extreme egg-shaped barrels and the corresponding horizontal and vertical measurements were noted as follows:

**Table 4.5.2 Internal Siphon Dimensions of
Halls Coulee Crossing Measured Fall 2004**

Left Pipe - Halls Coulee Crossing		
Station (ft)	Horizontal Width (ft)	Vertical Height (ft)
715+80	7'-3"	6'-3"
716+00	7'-0"	6'-2"
716+50	7'-2"	6'-3"
717+00	7'-3"	6'-2"
717+50	6'-10"	6'-6"
718+00	7'-0"	6'-2"
725+50	7'-0"	6'-1"
726+00	7'-0"	6'-2"
726+50	7'-0"	6'-3"
727+00	7'-0"	6'-2"
727+50	7'-0"	6'-4"
728+00	7'-0"	6'-3"
728+50	7'-0"	6'-3"
Right Pipe - Halls Coulee Crossing		
Station (ft)	Horizontal Width (ft)	Vertical Height (ft)
722+00	6'-9"	6'-5"
722+50	6'-10"	6'-4"

Note: Original diameter was 6'-6".

- The concrete inlet structure has major cracks at the joints. A significant amount of concrete has been plucked out of the concrete floor and side slopes, in the area of the flow passage.
- Rebar is exposed at the concrete inlet transition to the right pipe.

4.5.3 Rehabilitation Alternates

St. Mary River Siphon

The St. Mary River Siphon is in very poor condition and represents the most fragile component of the overall Diversion Facilities. Sudden failure could cause both economic and environmental catastrophes. Two concepts were considered by the BOR for replacing the St. Mary River Siphon. These include:

**Table 4.5.3 BOR Alternatives for Replacement of St. Mary River
And Halls Coulee Siphons**

<ul style="list-style-type: none"> • Alternative 1 	<ul style="list-style-type: none"> • Replace siphon with two new steel conduits out of the ground. Included are: • New inlet structure • New outlet structure • New upstream highway bridge • Replace existing bridge carrying siphon
<ul style="list-style-type: none"> • Alternative 2 	Replace siphon with two buried precast concrete pressure pipes, cross under the river, and construct a new highway bridge. Construct new inlet and outlet structures.

In both cases, a two-barrel replacement siphon system is to be relocated downstream (from river crossing) of the existing siphon. Both alternatives include buried pipe drains for slope stabilization hillsides, and stoplog slots to allow for isolation of one conduit, for maintenance.

The elevated steel pipe would require expansion/contraction joints and installation of deep-seated pipe supports resistant to surficial slope movements. Cathodic protection and pipe coatings would be required for the new steel pipe.

The concrete pressure pipe would not require cathodic protection, expansion/contraction joints, or a new bridge to cross the river. Hydraulic pressures would most likely dictate a prestressed section along the lower portions of the siphons.

Another alternative, which should be considered during the Feasibility Study, is to utilize a buried cast-in-place (CIP) concrete conduit. Cast-in-place concrete allows a single pipe option. At a velocity of 13 fps, a single pipe 9.0 to 10.0 feet in diameter would be required for 850 to 1000 cfs respectively. This type of siphon construction used was for replacement of the East Arrowwood Siphon in southern Alberta in 1999. For that project, the single siphon pipe diameter is 13.1 feet with a discharge capacity of 1800 cfs. A steel slip form was used to construct the CIP concrete siphon (Figures 4.5.16 through 4.5.18). The advantages of a single pipe siphon include a potential construction cost savings and essentially half the future maintenance.



Figure 4.5.16 Preparation of reinforced concrete footings and foundation concrete. Note conduit construction in background (July 1999).



Figure 4.5.17 Close up of steel slip form partly in place in preparation of placing a 30 foot length of siphon (July 1999).

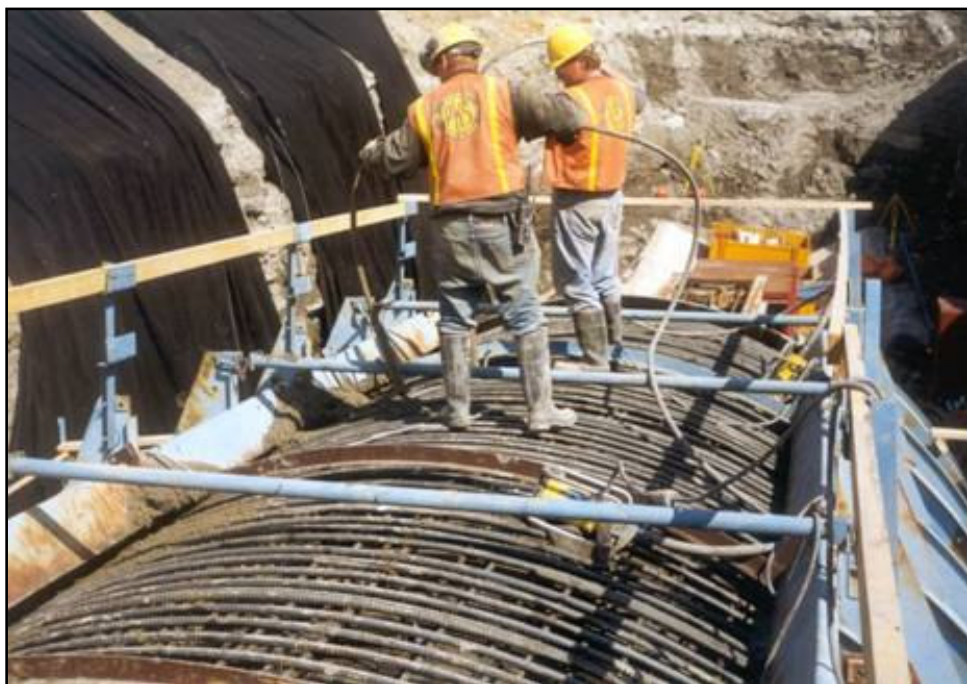


Figure 4.5.18 Filling form with concrete (July 1999).

Halls Coulee Siphon

The condition of Halls Coulee is less severe than that of the St. Mary River Siphon. The BOR recommended two siphon replacement alternatives for Halls Coulee that are essentially the same as for the St. Mary River Siphon: buried precast concrete and elevated steel pipes. Both alternatives would utilize a two-pipe replacement scheme.

We believe the cast-in-place alternative described above for the St. Mary River crossing should also be considered and evaluated for Halls Coulee as a considerable cost savings to the BOR's alternatives.

A fourth alternative is to construct an earthen fill embankment across Halls Coulee. The canal would cross atop the fill in a lined, two-bank section. The embankment would incorporate internal drainage and geogrid reinforcement. Cross drainage, wildlife crossings and access to the buried crude oil pipeline could be maintained using pre-cast concrete arch sections. The existing siphon pipes could be filled and abandoned in-place.

4.5.4 Estimated Rehabilitation Costs

The BOR cost estimates (March 2003) for the St. Mary River and Halls Coulee siphons are summarized below. We have adjusted the costs for a 2007 construction season ($\times 1.1255$) and included 5% for Tribal fees. The prices below are for the precast concrete pressure pipe alternative, which is the BOR recommendation. In our opinion, a single barrel, cast-in-place alternative would be a potentially significant cost savings at both siphon locations. The cost per lineal foot for the Arrowwood Siphon in Alberta was approximately \$3330/LF (1998 prices). This siphon had a 13.1-foot diameter and an 1800 cfs capacity. Based on the 1000 cfs projected costs (list below), the St. Mary River and Halls Coulee siphons costs for the BOR's alternative are \$4215/LF and \$3535/LF for the 3225-ft. and 1405-ft. crossings, respectively. The earthen embankment option for Halls Coulee also could be less expensive.

**Table 4.5.4 Cost Estimates to Rehabilitate the St. Mary River
And Halls Coulee Siphons**

Canal Capacity	BOR Cost Estimates - 2003		Projected Costs - 2007 ¹	
	St. Mary River	Halls Coulee	St. Mary River	Halls Coulee
500 cfs	\$6,200,000	\$3,300,000	\$7,327,100	\$3,899,900
670 cfs	\$7,500,000	\$3,400,000	\$8,863,400	\$4,018,100
850 cfs	\$8,500,000	\$4,100,000	\$10,045,200	\$4,845,300
1000 cfs	\$11,500,000	\$4,200,000	\$13,590,500	\$4,963,500

(1) = [(BOR Cost) * 1.1255] * 1.05

4.5.5 Rehabilitation Schedule

The St. Mary River Siphon should be the first structure of the overall Diversion Facilities to be rehabilitated due to its serious condition and potential for catastrophic failure. Each of the replacement alternatives could be constructed during the normal water diversion season with the transitions to the existing canal being completed during October to March. We anticipate a two-year construction duration per siphon facility depending on environmental restrictions. Designs for each siphon location should not be finalized until the geotechnical and slope stability studies (Section 7.2) have been completed. Construction of the siphons should not begin until the existing St. Mary Bridge is replaced with a new structure capable of supporting construction-related loads.

**Table 4.5.5 Estimated Time to Rehabilitate St. Mary River
And Halls Coulee Siphons**

Task	Duration
1) Replacement Bridge at St. Mary River	Prerequisite
2) Slope Stability Analyses	12-18 months
3) Feasibility Studies, Both Sites	6 months
4) Final Designs, Per Site	6 months
5) Construction Phases, Per Site	18-24 months
TOTAL TIME	42-54 months

4.6 HYDRAULIC DROPS

4.6.1 Structure Overview

The St. Mary canal empties into the North Fork of the Milk River after passing through five reinforced concrete drop structures. The total drop created by these structures is approximately 218 feet. The drop structures were originally designed by the BOR and construction was completed in 1915. The structures are similar in longitudinal and transverse section but vary in length and overall drop. The structures are numbered 1 to 5, from upstream to downstream.

Throughout the years, various concrete repairs have been made to the drop structures. These repairs have ranged from grouting of cracks in the slabs and side walls to replacement of entire sections of a structure due to concrete deterioration and failure. Maintenance of these structures has been a regular practice over the years and to date is an ongoing process. A recent failure within Drop No. 2 resulted in replacement of an entire chute and side wall section within that structure.

4.6.2 Existing Conditions and Deficiencies

An initial cursory inspection of the canal and drop structures was performed by the project team on October 13, 2004. Each of the five drop structures were inspected in further detail during a site visit on November 10, 2004. The system was not in operation at the time of the inspections. However, the plunge pools were inundated, which prevented a complete inspection of the plunge pool slab and lower walls.